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**TURBINE POWER
CONTROL VALVE ACTUATOR SYSTEM
MODEL NT-B4
PART NO. 2775004, SERIAL NO. 9
TEST DATA AND RESULTS (U)**

NASA-CR-136925) TURBINE POWER CONTROL
VALVE ACTUATING SYSTEM BENDIX MODEL NO.
T-B4 PART NO. 2775004, SERIAL NO. 9
Bendix Corp.) 34 p

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BENDIX PRODUCTS AEROSPACE DIVISION
SOUTH BEND 20, INDIANA**

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BENDIX MODEL NO. NT-B4
PART NUMBER 2775004, SERIAL NO. 9 (U)**

TEST DATA AND RESULTS

June 1963


Submitted to

Aerojet - General Corporation
Azusa, California

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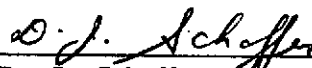

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SECTION I

INTRODUCTION

This report presents the results of the tests performed to evaluate the Turbine Power Control Valve Actuator, Model NT-B4, Part Number 2775004, Serial Number 9. All tests were conducted at the Bendix Products Aerospace Division of the Bendix Corporation, South Bend, Indiana, during April and May, 1963. After testing was completed the actuator was shipped to the Aerojet-General Corporation on May 17, 1963.

The testing included component evaluation tests, actuator performance tests at room temperature, actuator performance tests at low temperature, and a final calibration before shipment.

Reproductions of actual actuator test data are included in this report.

SECTION II

COMPONENTS AND TEST RESULTS

2.1 MAGNETIC AMPLIFIER (Part Number 179818, Serial Number 5)

A schematic diagram of the magnetic amplifier after system compensation is shown in figure 2-1.

2.2 TORQUE MOTOR (Part Number 2151818, Serial Number 110)

Figure 2-2 shows the relationship between the differential current supplied to the torque motor coils and the flapper travel. Figure 2-3 provides a plot of amplitude ratio and phase shift versus frequency as observed during a frequency response test of this torque motor.

2.3 SERVO VALVE (Part Number 2775104, Serial Number 11)

Figure 2-4 shows the dead ended pressure measured at the P_1 and P_2 port versus the differential current supplied to the torque motor. Figure 2-5 represents the input flow to the servo valve as related to the differential current supplied to the torque motor.

Both curves are plots of actual test data taken with torque motor 2151818, Serial Number 117. The torque motor shipped as part of the actuator is Part Number 2151818, Serial Number 110.

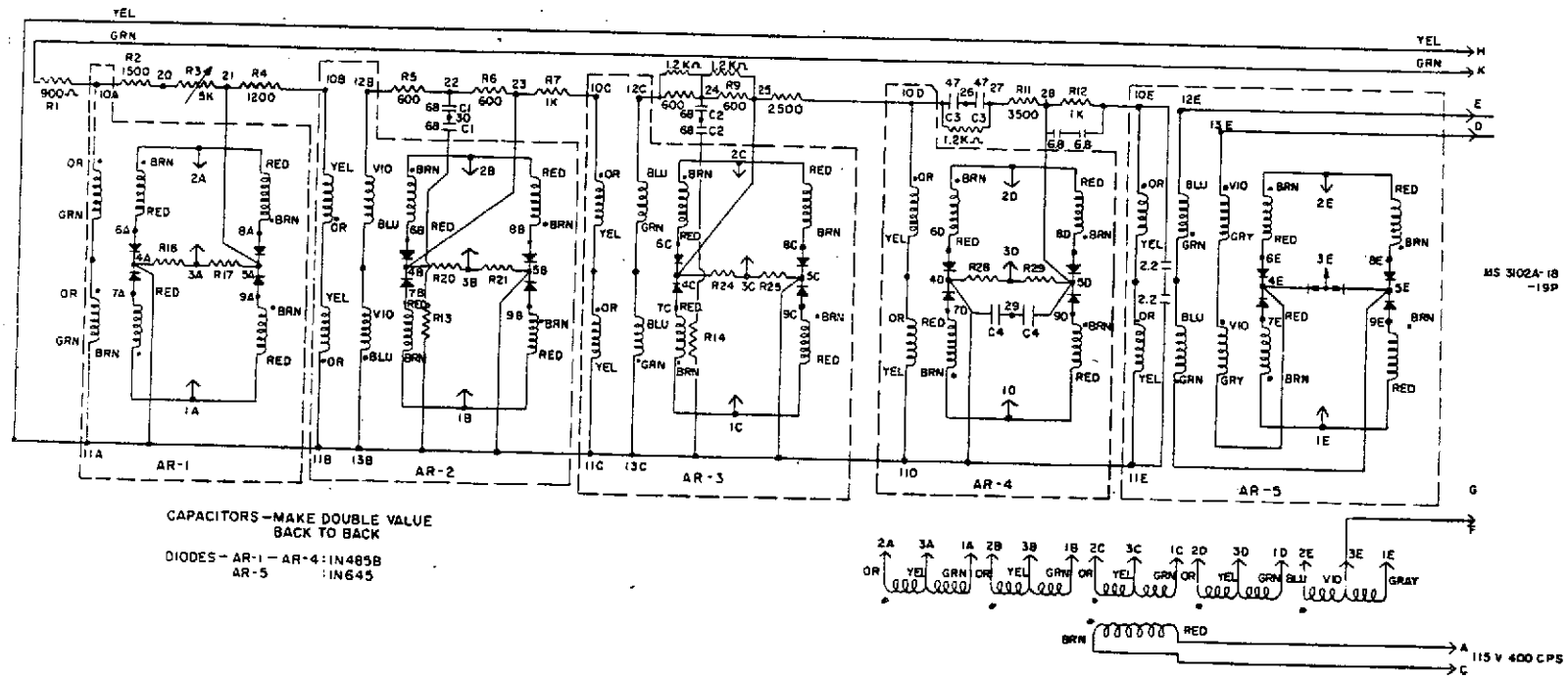


Figure 2-1. Schematic Diagram of Magnetic Amplifier

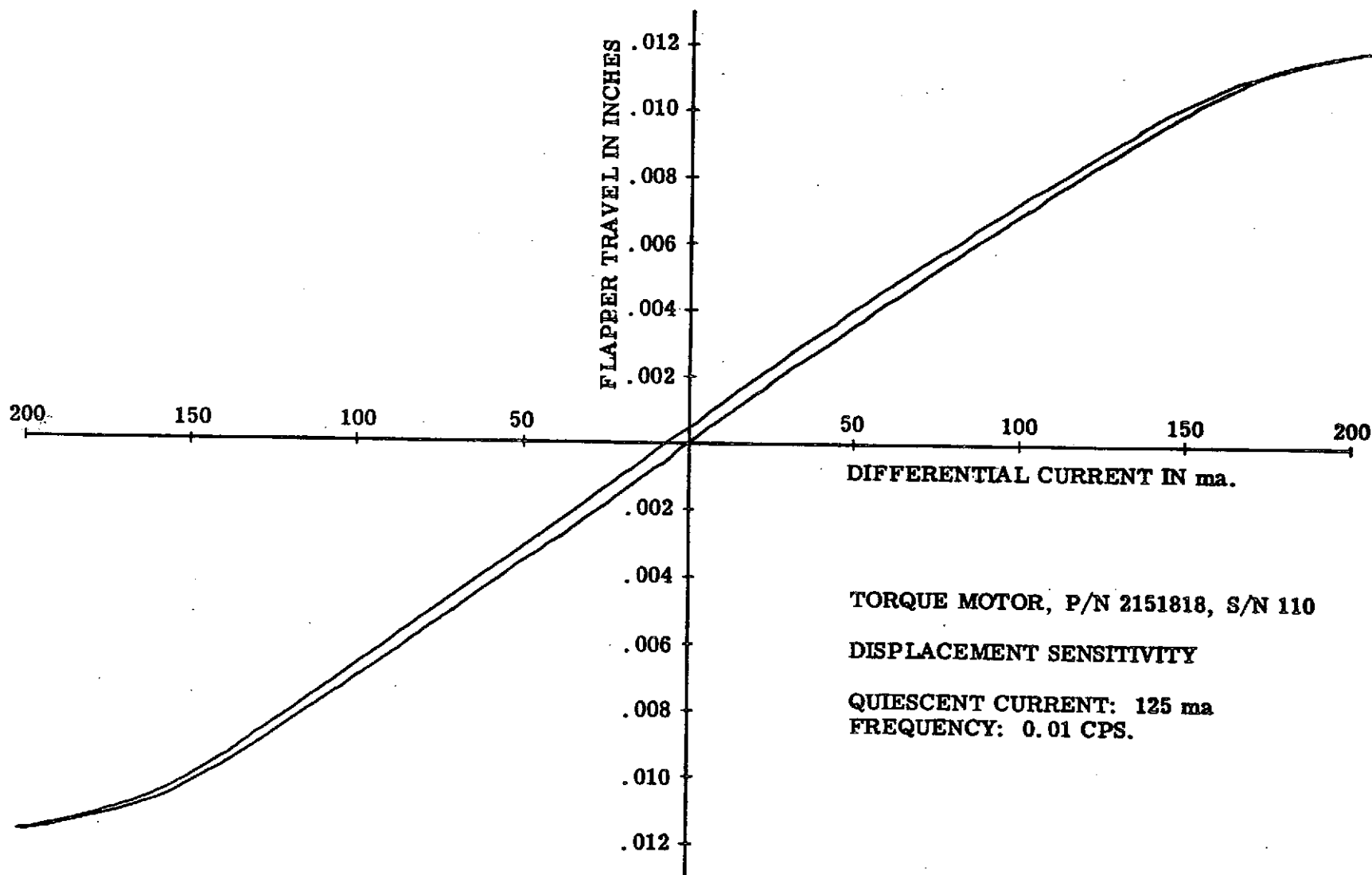


Figure 2-2. Differential Current Versus Flapper Travel

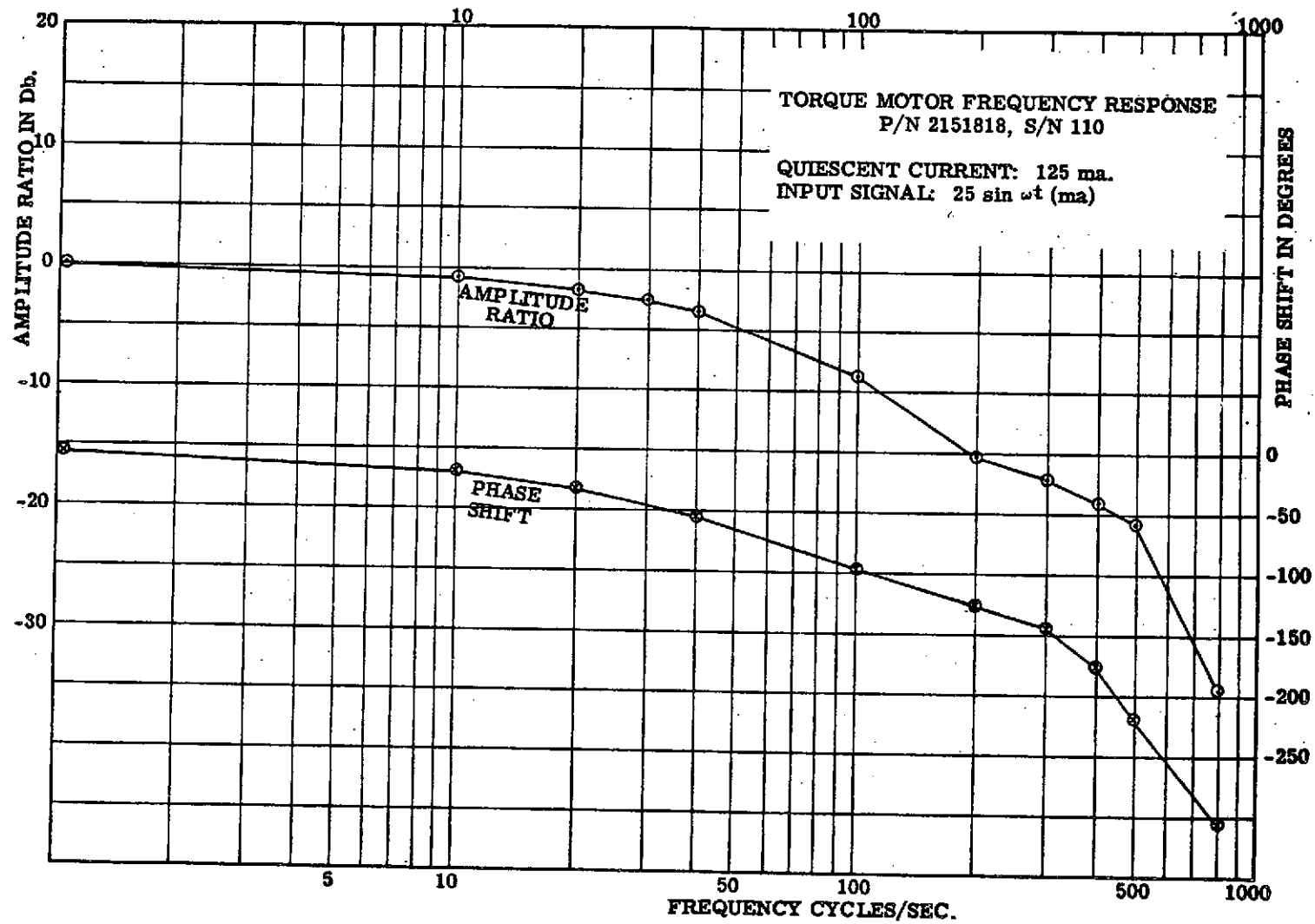


Figure 2-3. Amplitude Ratio and Phase Shift Versus Frequency

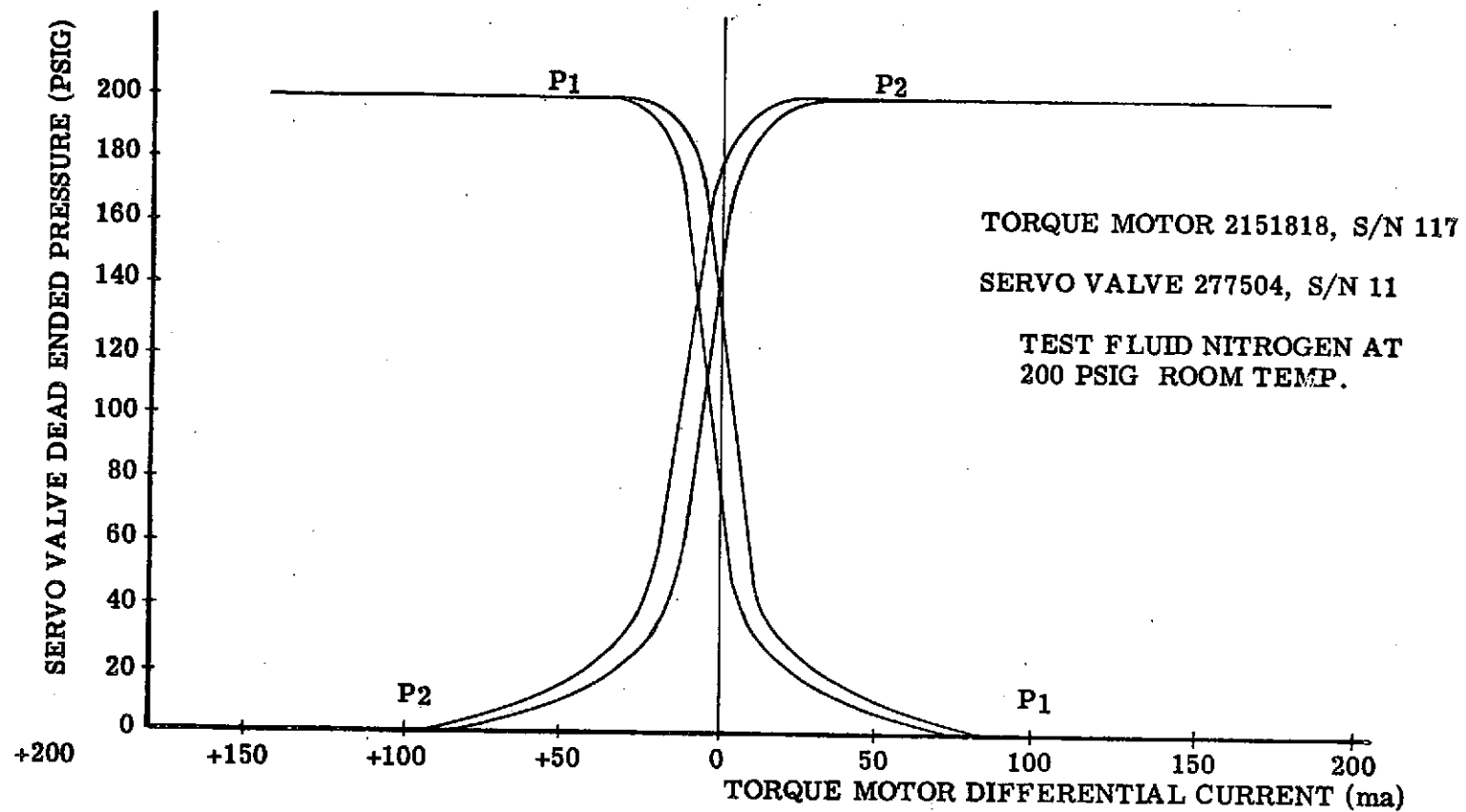
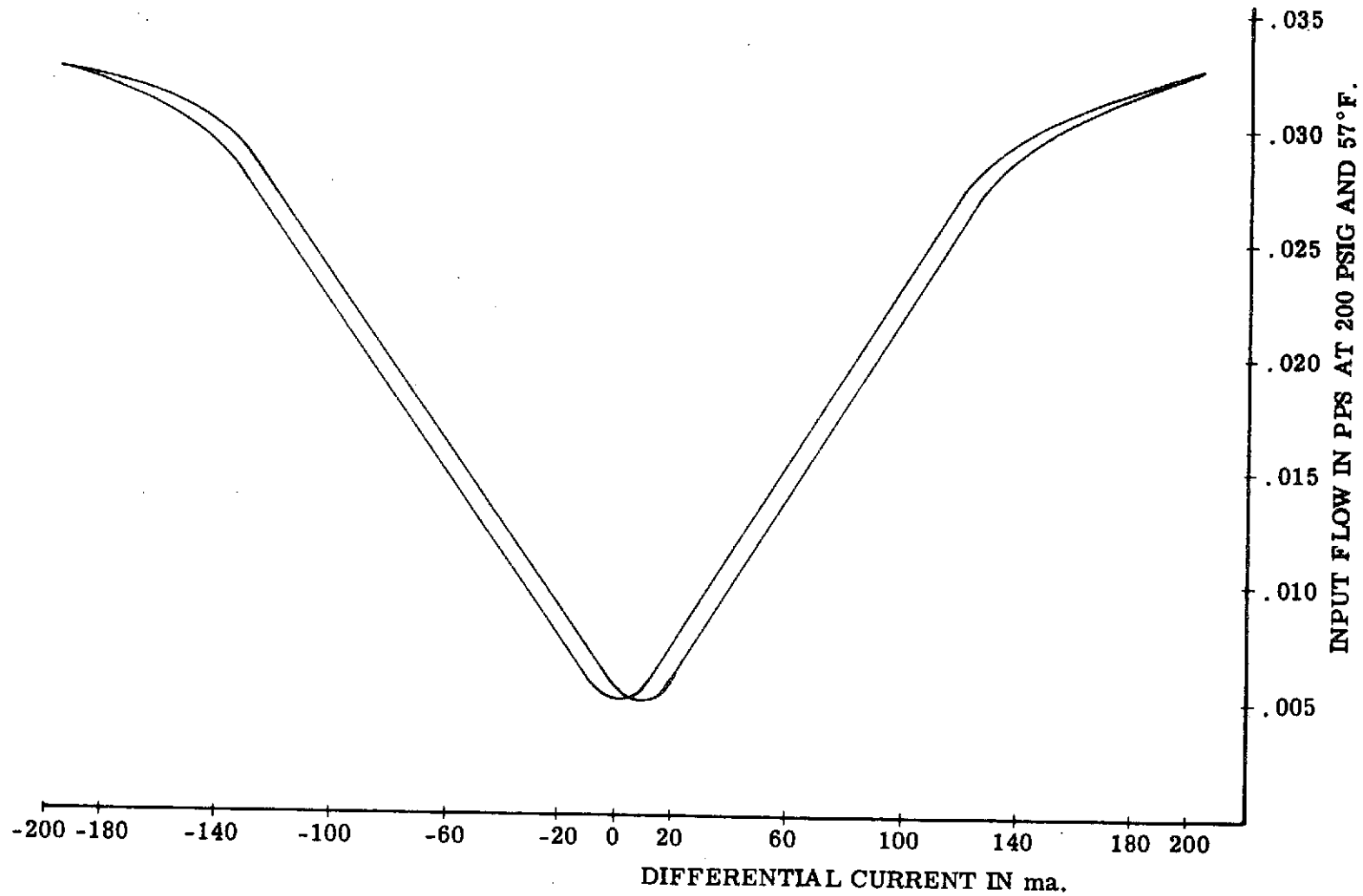


Figure 2-4. Dead Ended Pressure Versus Differential Current



SERVO VALVE 2775104, S/N 11
TORQUE MOTOR 2151818, S/N 117

TEST FLUID: NITROGEN AT 200 PSIG.

Figure 2-5. Input Flow-to-Servo Valve Versus Differential Current to Torque Motor

2.4 GEAR MOTOR

(Part Number 2150806, Serial Number 6)

Figure 2-6 shows the relationship of the differential pressure of the gear motor inlet and exhaust ports versus the flow at stalled condition and the corresponding stall torque developed.

Figure 2-7 is a plot of the stall torque developed by the gear motor versus the differential current supplied to the torque motor, servo valve, gear motor combination.

Figure 2-8 shows the no-load speed characteristics of this combination.

2.5 TRANSMISSION

(Part Number 2775005, Serial Number 2)

The following characteristics apply to this transmission:

Efficiency 83.5% at 1000 rpm with 370 in. -lbs. torsional load

Efficiency 83% at 1000 rpm with 740 in. -lbs. torsional load

Breakout torque 1 in. -ounce on input shaft

Backlash 0.00016 rad/max measured on output shaft with 2 in. -lbs. of torque

Stiffness at from 0 to 200 in. -lbs. load on output shaft 60,600 in. -lbs. /radians.

2.6 POTENTIOMETERS

(Part Number 2775306)

- 2.6.1 Feedback potentiometer, element 3D8596 case 3D5781
Instrumentation potentiometer, element 3D8595 case 3D5781

- 2.6.2 The conductive "doping" content of the slip ring in these potentiometers has been modified (resulting in slightly increased resistance) to eliminate the malfunction previously encountered during cryogenic temperature testing. No malfunction of these potentiometers was observed during either component acceptance testing or actuator testing.

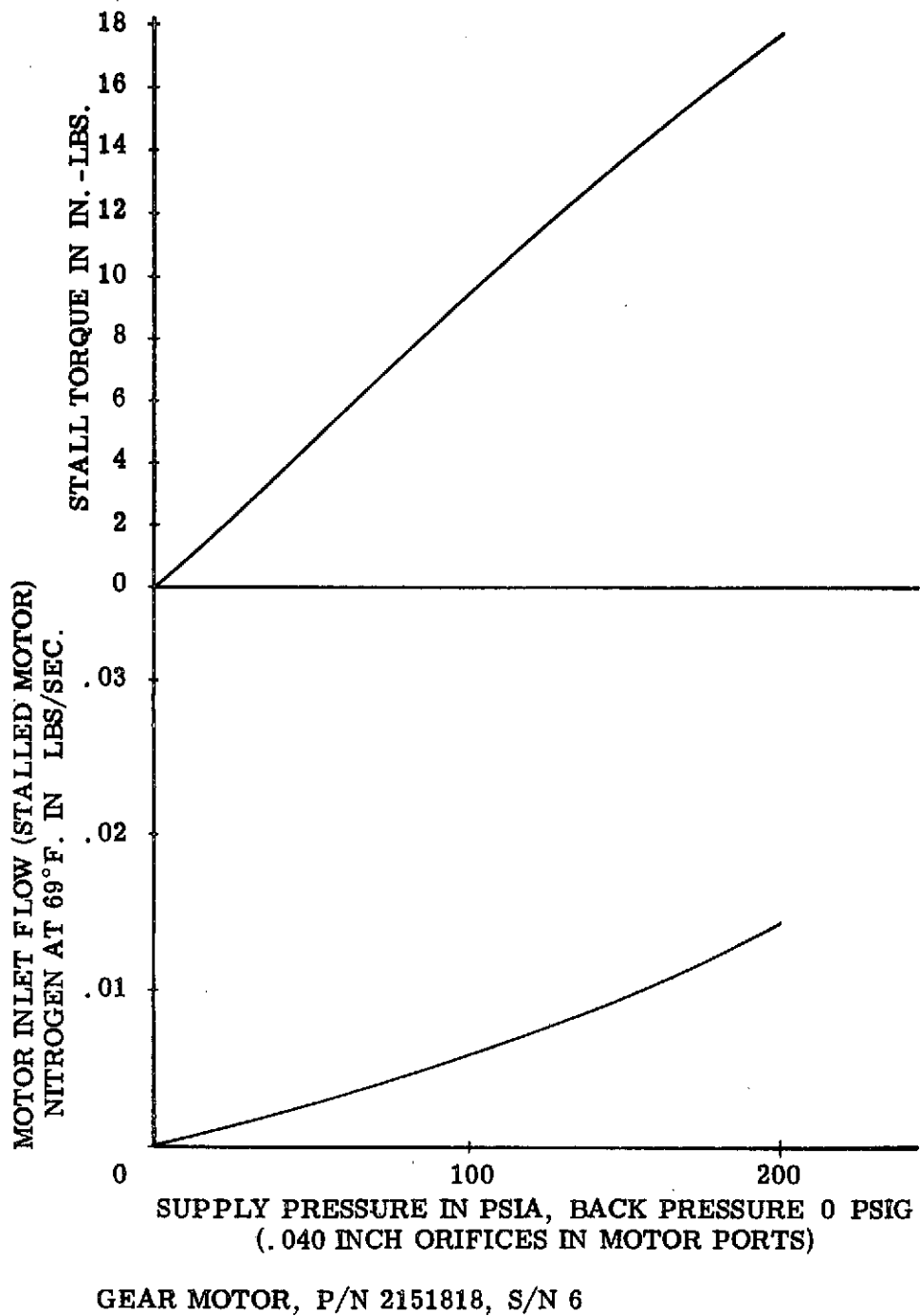


Figure 2-6. Stall Torque Versus Differential Pressure and Flow Torque Versus Differential Pressure

TORQUE MOTOR, P/N 2151818, S/N 117
 SERVO VALVE, P/N 2775104, S/N 11
 GEAR MOTOR, P/N 2150806, S/N 6

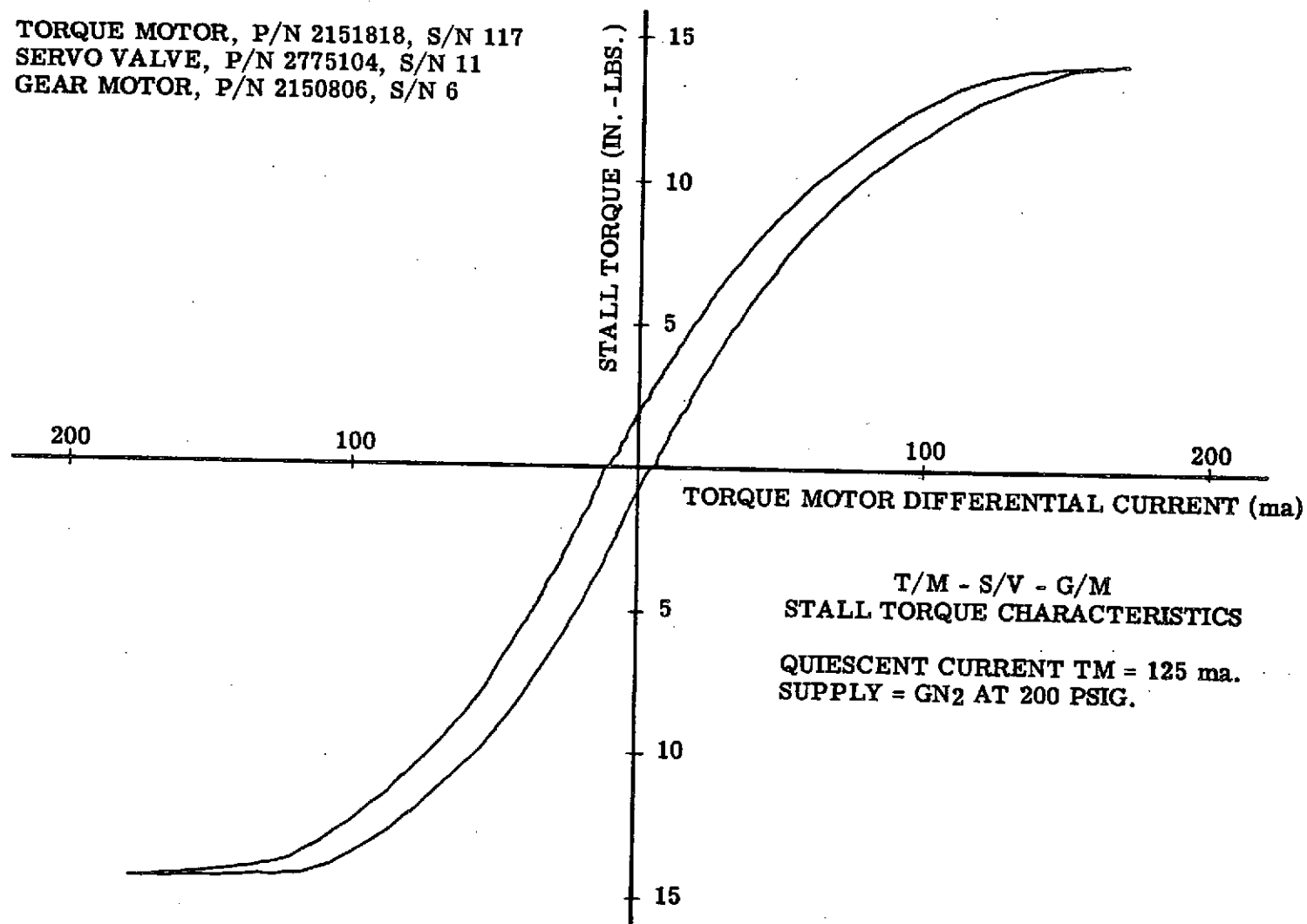


Figure 2-7. Stall Torque Versus Differential Current

TORQUE MOTOR, P/N 2151818, S/N 117
 SERVO VALVE, P/N 2775104, S/N 11
 GEAR MOTOR, P/N 2150806, S/N 6

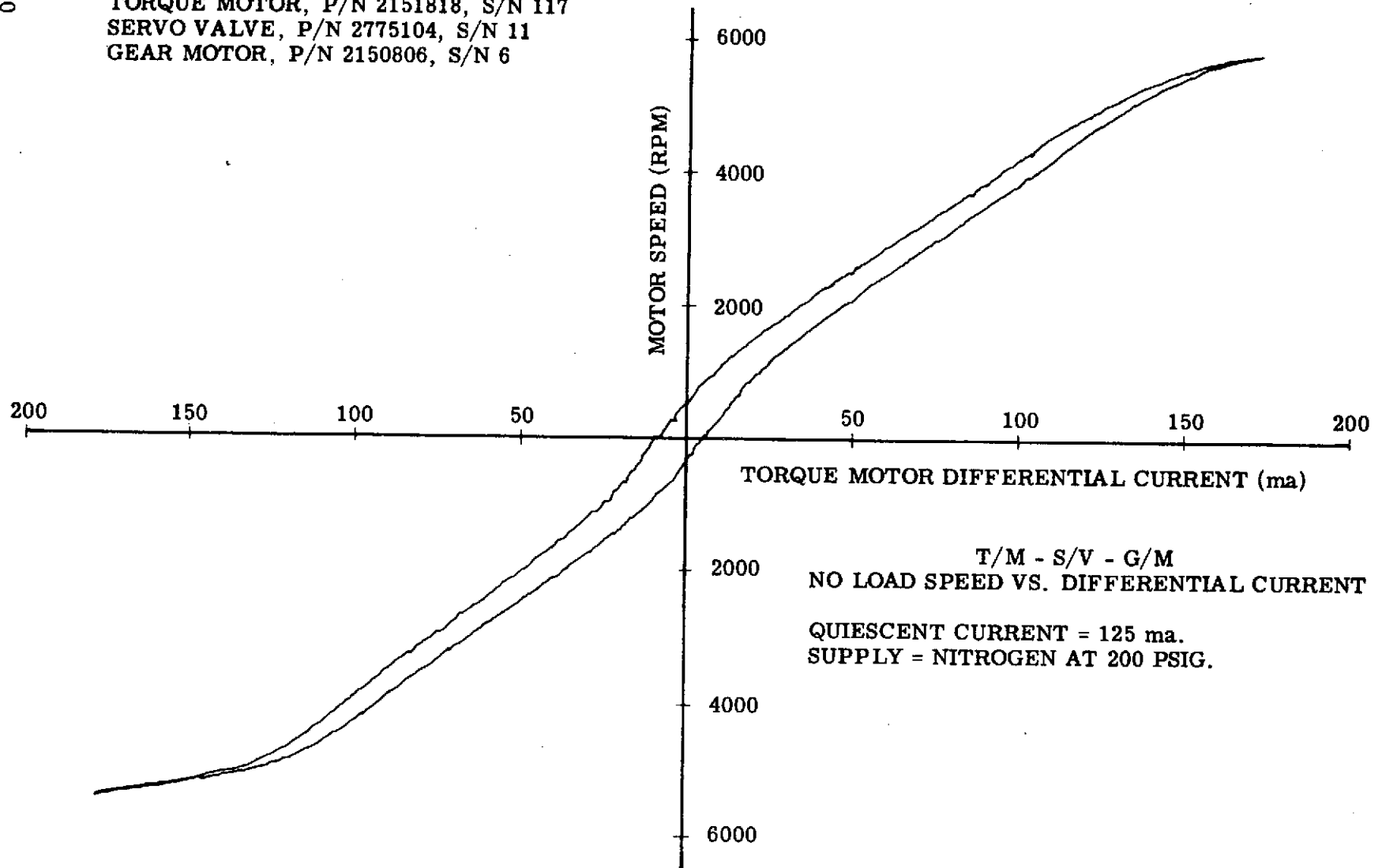


Figure 2-8. Motor Speed (RPM) Versus Torque Motor Differential Current (MA)

The potentiometer settings were made in accordance with figure 2-9.

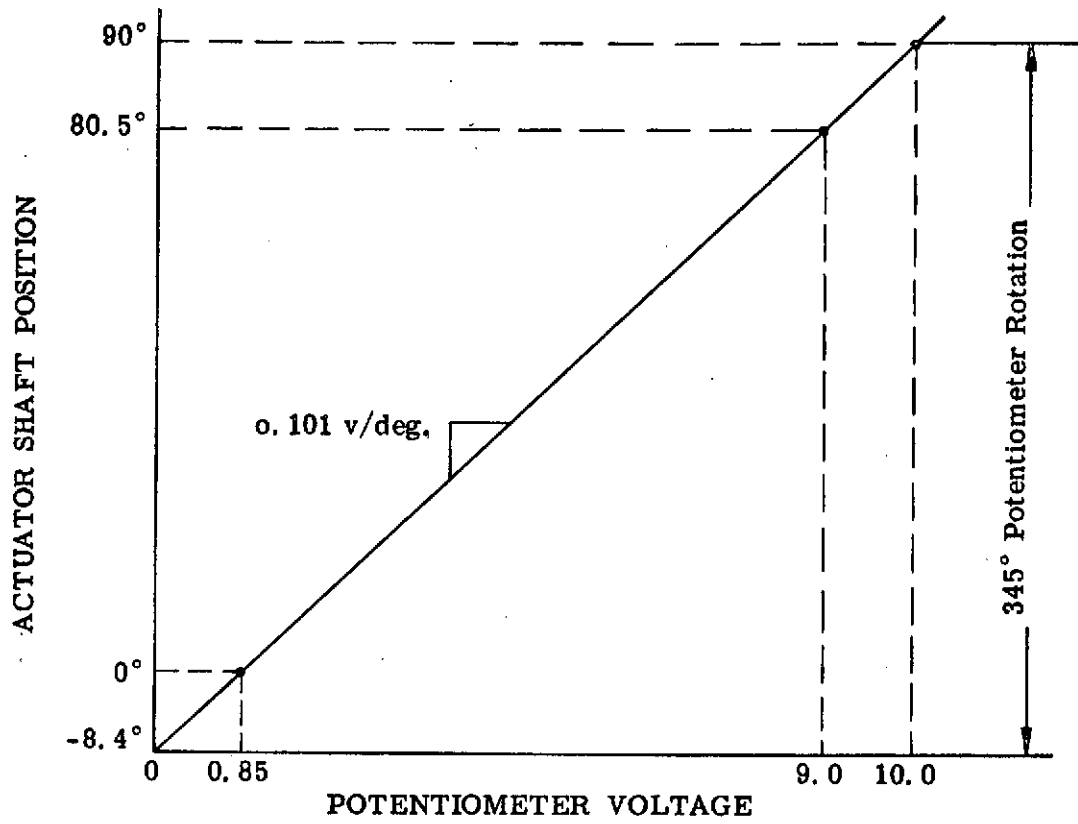


Figure 2-9. Potentiometer Voltage Relationship to Actuator Shaft Position

SECTION 3

ACTUATOR TEST RESULTS

After all component testing was completed, the actuator was assembled and tested as a system. The actuator performance was compared to the performance criteria in paragraph 3.1.

3.1 PERFORMANCE CRITERIA

3.1.1 Transient Response

The response of the actuator to an input step amplitude equal to 45 degrees from any actuator output shaft position greater than 5 degrees, shall be such that 62 percent of the corresponding output level shall be achieved within 0.12 second. Following a transient disturbance to the input of the actuator, the overshoot of the output shaft motion shall not exceed 20 percent of the ordered output level and the output shaft position shall be restrained to within 5 percent of the ordered step within 0.3 second.

3.1.2 Slew Velocity

Under loaded conditions, the slew velocity shall be 360°/second, minimum.

3.1.3 Dynamic Resolution

The resolution of the actuator shall be ± 0.5 degrees from the ordered position when the actuator is driven with a one-degree per second ramp at 0.05 cps. When coupled to the turbine power control valve, the resolution requirement is effective in the 5° to 90° actuator output shaft position range.

3.1.4 Frequency Response

The response of the actuator to a sinusoidal input signal of ± 2 degrees amplitude shall approximate a second-order system with a break point at a nominal 8 cps with a 0.5 damping ratio minimum.

3.2 ACTUATOR SYSTEM PERFORMANCE TESTS

Table 3-1 summarizes all the performance testing and test results obtained on the actuator system. The test conditions are shown in Table 3-2. Reproductions of the actual Sanborn Recorder traces taken during the testing are shown in Figures 3-1 through 3-12.

3.3 FINAL CALIBRATION BEFORE SHIPMENT

Before shipment, the actuator was recalibrated. Actual Sanborn Recorder traces of these tests are reproduced in Figure 3-12.

3.4 TOTAL ACCUMULATED TEST TIME

The total accumulated test time on the actuator assembly was 26.8 hours.

Time accumulated on the individual components before they were combined into the actuator assembly was as follows:

Torque Motor, P/N 2151818, S/N 110 - 1.5 hours.
(Actuator testing was started with Torque Motor, S/N 117 which malfunctioned after 5.3 hours of actuator testing. Torque Motor, S/N 117 was replaced with S/N 110 at this point.)

Servo Valve, P/N 2775104, S/N 11 - 18.4 hours.

Gear Motor, P/N 2150806, S/N 6 - 24.7 hours.

Transmission, P/N 2775005, S/N 2 - 0.8 hours.

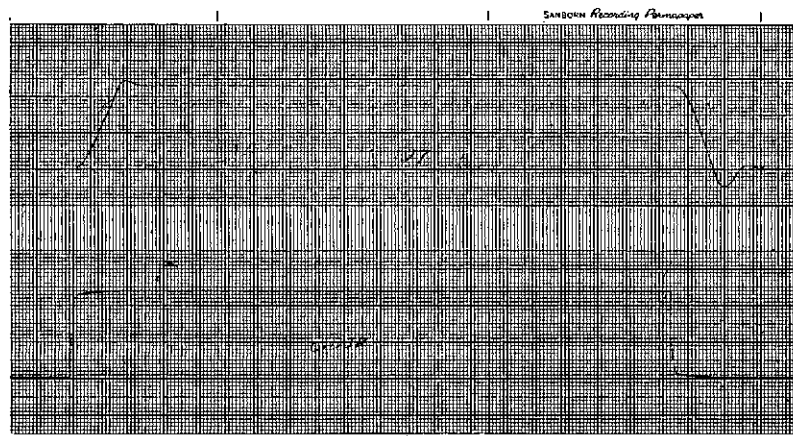
Table 3-1. Summary of Tests and Test Results

Test	Test Condition	Forcing Function	Test Results	Figure Number
Transient Response	A	45° Step at 0.3 cps. around 42°	Overshoot: 20.6% 62% Rise Time: 0.10 sec. Settling Time: 0.19 sec.	3-1A
Slew Velocity	A	45° Step at 0.3 cps. around 42°	435 °/sec. increase angle 597 °/sec. decrease angle	3-1A
Dynamic Resolution	A	± 5° Ramp at 0.05 cps. around 20°	Resolution ±0.15°	3-1C
Static Resolution	A	0.1 cps Sine Wave around 20°	Resolution ±0.038°	3-1B
Frequency Response	A	±2° Sine Wave around 20°	90° Phase Lag at 11 cps 180° Phase Lag at 22 cps	3-2 3-3
Frequency Response	A	±2° Sine Wave around 60°	90° Phase Lag at 11 cps 180° Phase Lag at 22 cps	3-4 3-5
Transient Response	B	45° Step at 0.3 cps around 42°	Overshoot 19.5% 62% Rise Time 0.11 sec. Settling Time 0.23 sec.	3-6A
Slew Velocity	B	45° Step at 0.3 cps. around 42°	313 °/sec. increase angle 358 °/sec. decrease angle	3-6A
Dynamic Resolution	B	±5° Ramp at 0.05 cps. around 20°	Resolution ±0.25°	3-6C
Dynamic Resolution	B	±5° Ramp at 0.05 cps. around 60°	Resolution ±0.38°	3-6D
Frequency Response	B	±2° Sine Wave around 20°	90° Phase Lag at 11 cps. 180° Phase Lag at 22 cps.	3-7 3-8
Transient Response	C	45° Step at 0.3 cps. around 42°	Overshoot 8.7% 62% Rise Time 0.18 sec. Settling Time 0.295 sec.	3-9A
Slew Velocity	C	45° Step at 0.3 cps. around 42°	170 °/sec. increase angle 244 °/sec. decrease angle	3-9A
Dynamic Resolution	C	±5° Ramp at 0.05 cps. around 20°	Resolution ±0.13°	3-9C
Static Resolution	C	0.1 cps Sine Wave around 20°	Resolution ±0.1°	3-9B
Frequency Response	C	±2° Sine Wave around 20°	90° Phase Lag at 12 cps. 180° Phase Lag at 22 cps.	3-10 3-11

Table 3-2. Test Conditions

Test Condition	External Friction Load (In-Lb)	Torsional Spring Rate (In-Lb/Deg)	Shaft Seal Pressure (PSIG)	Actuator Exhaust Back Pressure (PSIG)	Gas Inlet Temp. (OF)	Gas
A	0	2.67	650	45	60	Hydrogen
B	0	2.67	650	45	-277	Hydrogen
C	0	2.67	650	45	60	Nitrogen

All performance was recorded using 215 psia supply gas pressure.

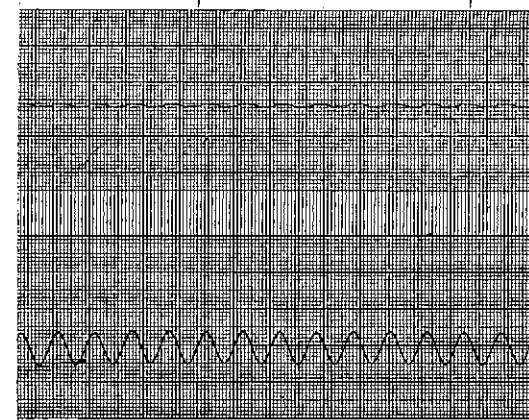


OUTPUT SHAFT
POSITION:
2.0 DEGREES/MM

STEADY-STATE
OUTPUT SHAFT
POSITION: 42°

INPUT COMMAND
SIGNAL:
45 DEGREE STEP

A. TRANSIENT RESPONSE AND SLEW VELOCITY
PAPER SPEED: 100 MM/SEC.



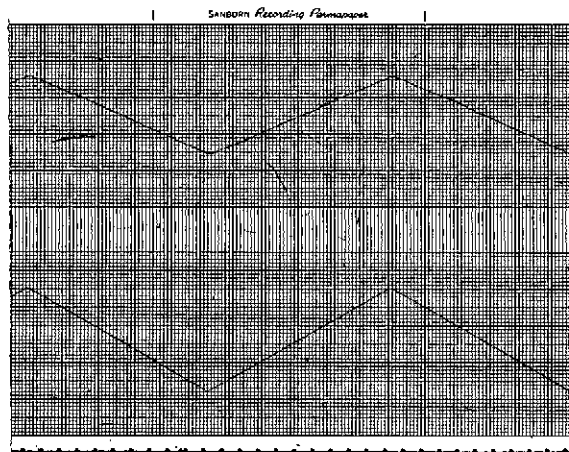
OUTPUT SHAFT
POSITION:
0.01 DEGREE/MM

STEADY-STATE
OUTPUT SHAFT
POSITION: 20°

INPUT COMMAND
SIGNAL: 0.075°
0.1 CPS SINE WAVE

B. STATIC RESOLUTION
PAPER SPEED: 1 MM/SEC.

Friction Load: 0 in. -lb.	Load Spring Rate: 2.67 in. -lb./deg.
Exhaust Pressure: 45 psig.	Gas: Hydrogen
Shaft Seal Pressure: 650 psig.	Gas Temperature: 60°F.
	Supply Pressure: 200 psig.

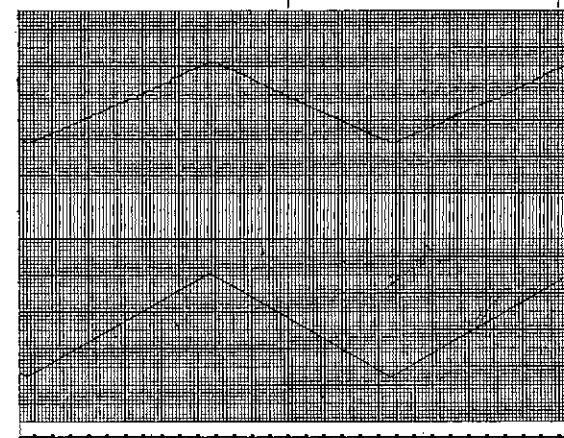


OUTPUT SHAFT
POSITION:
0.5 DEGREES/MM

STEADY-STATE
OUTPUT SHAFT
POSITION: 20°

INPUT COMMAND
SIGNAL:
± 5 DEGREE RAMP
AT 0.05 CPS

C. DYNAMIC RESOLUTION
PAPER SPEED: 5 MM/SEC.



OUTPUT SHAFT
POSITION:
0.5 DEGREES/MM

STEADY-STATE
OUTPUT SHAFT
POSITION: 60°

INPUT COMMAND
SIGNAL:
± 5 DEGREE RAMP
AT 0.05 CPS

D. DYNAMIC RESOLUTION
PAPER SPEED: 5 MM/SEC.

Figure 3-1. Closed Loop Performance of TPCV Actuator (NT-B4 No. 9) Test Condition A

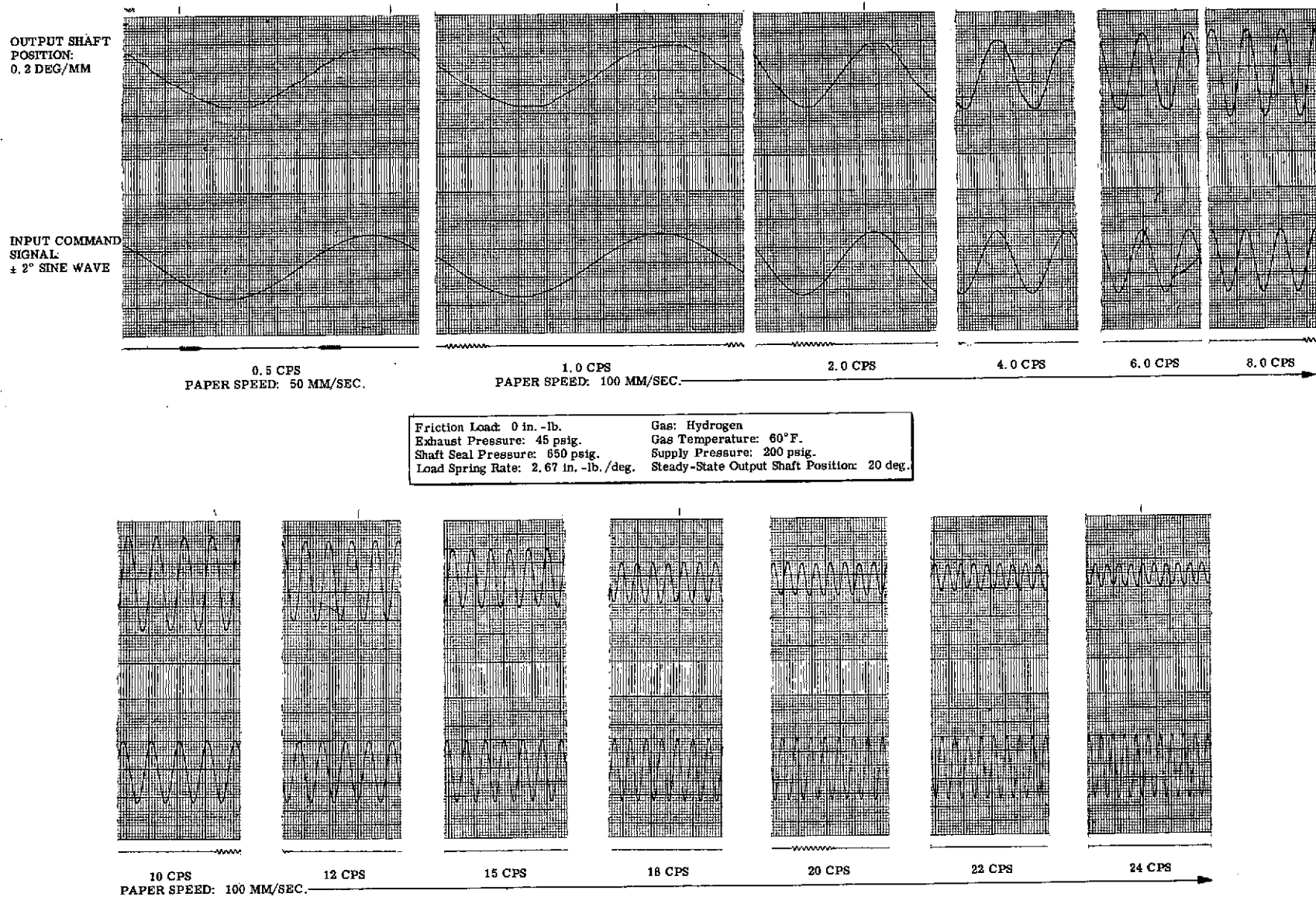


Figure 3-2. Frequency Response for Test Condition A

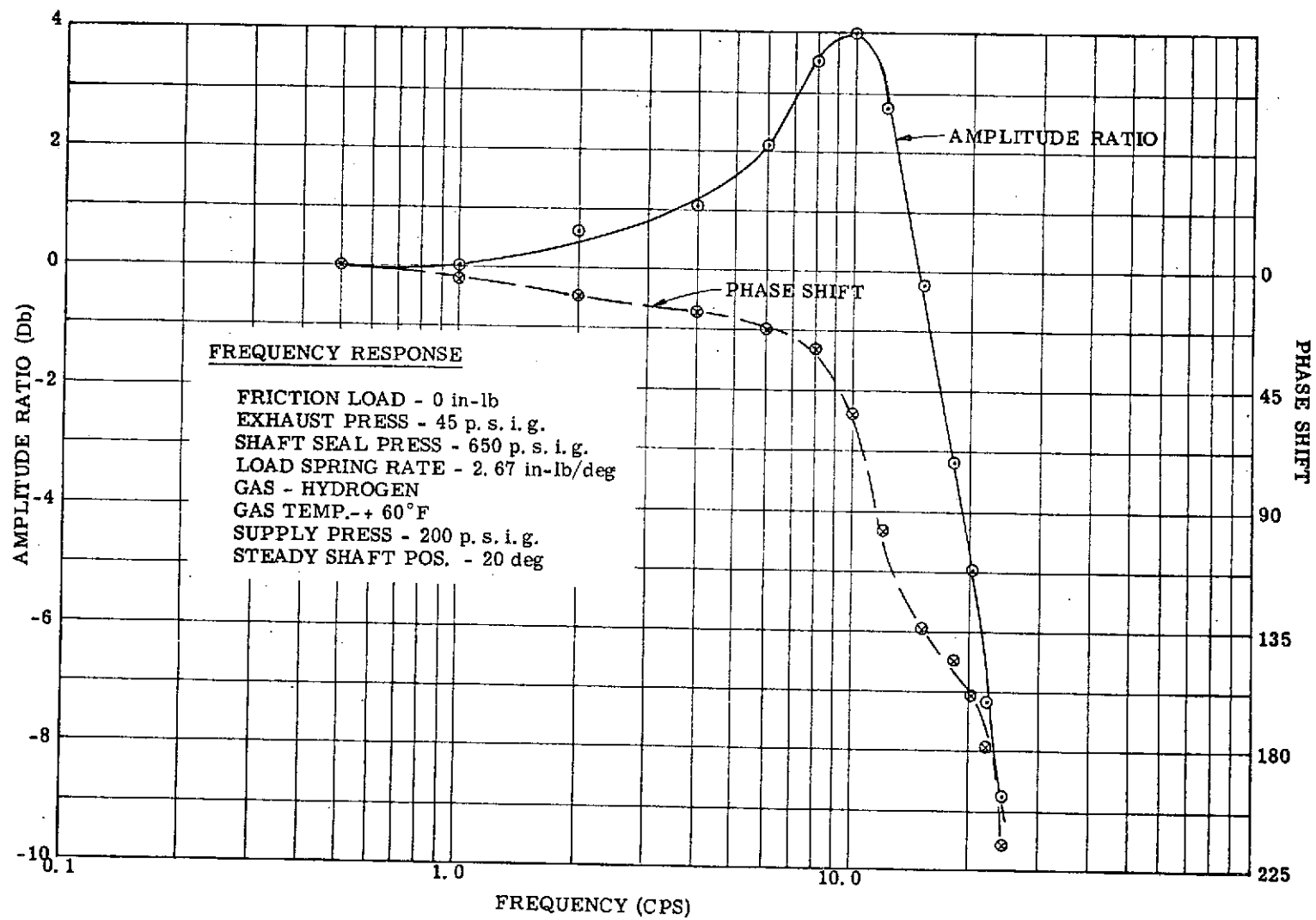


Figure 3-3. Amplitude Ratio and Phase Shift Versus Frequency (CPS)

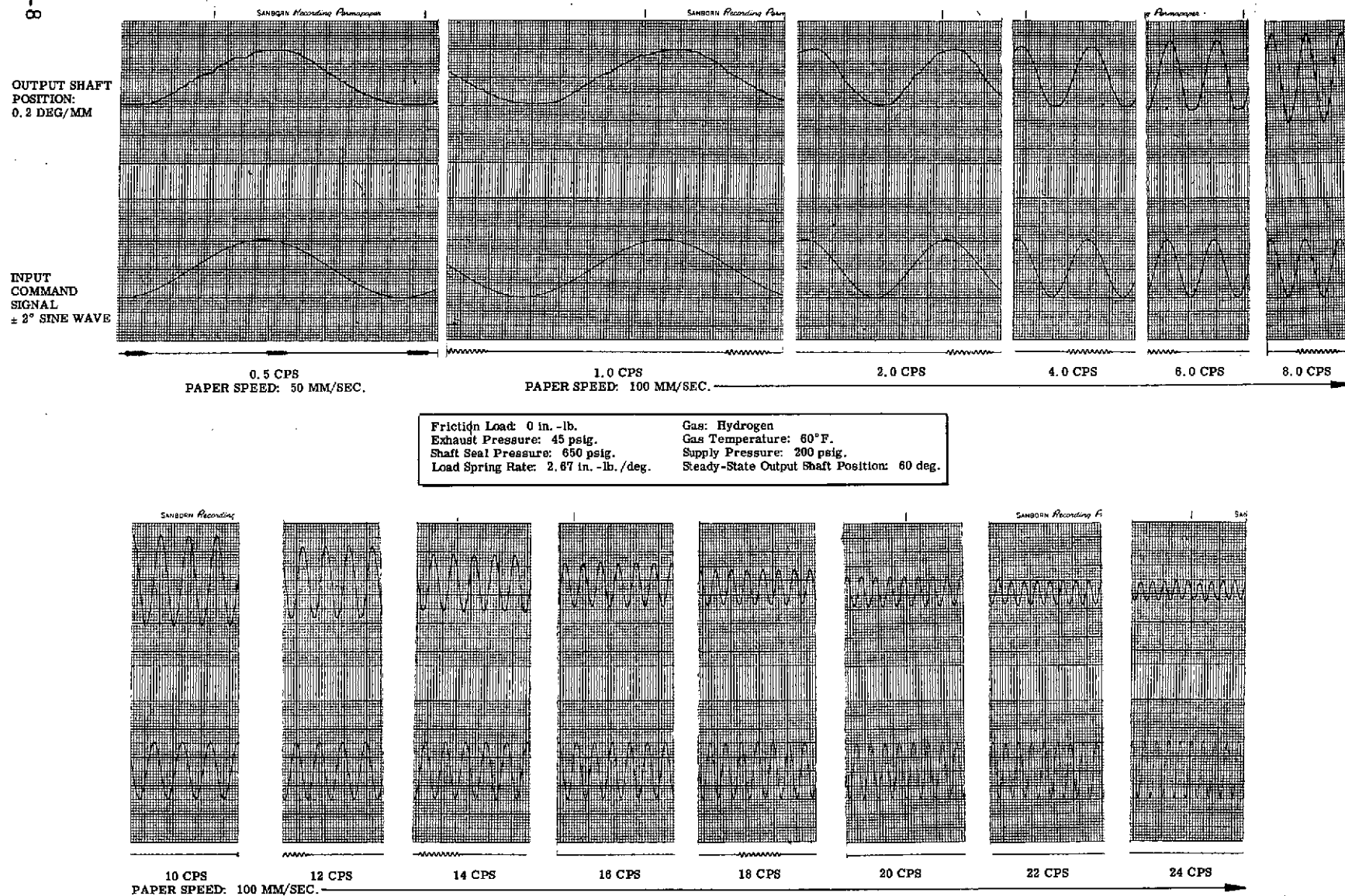


Figure 3-4. Frequency Response for Test Condition A

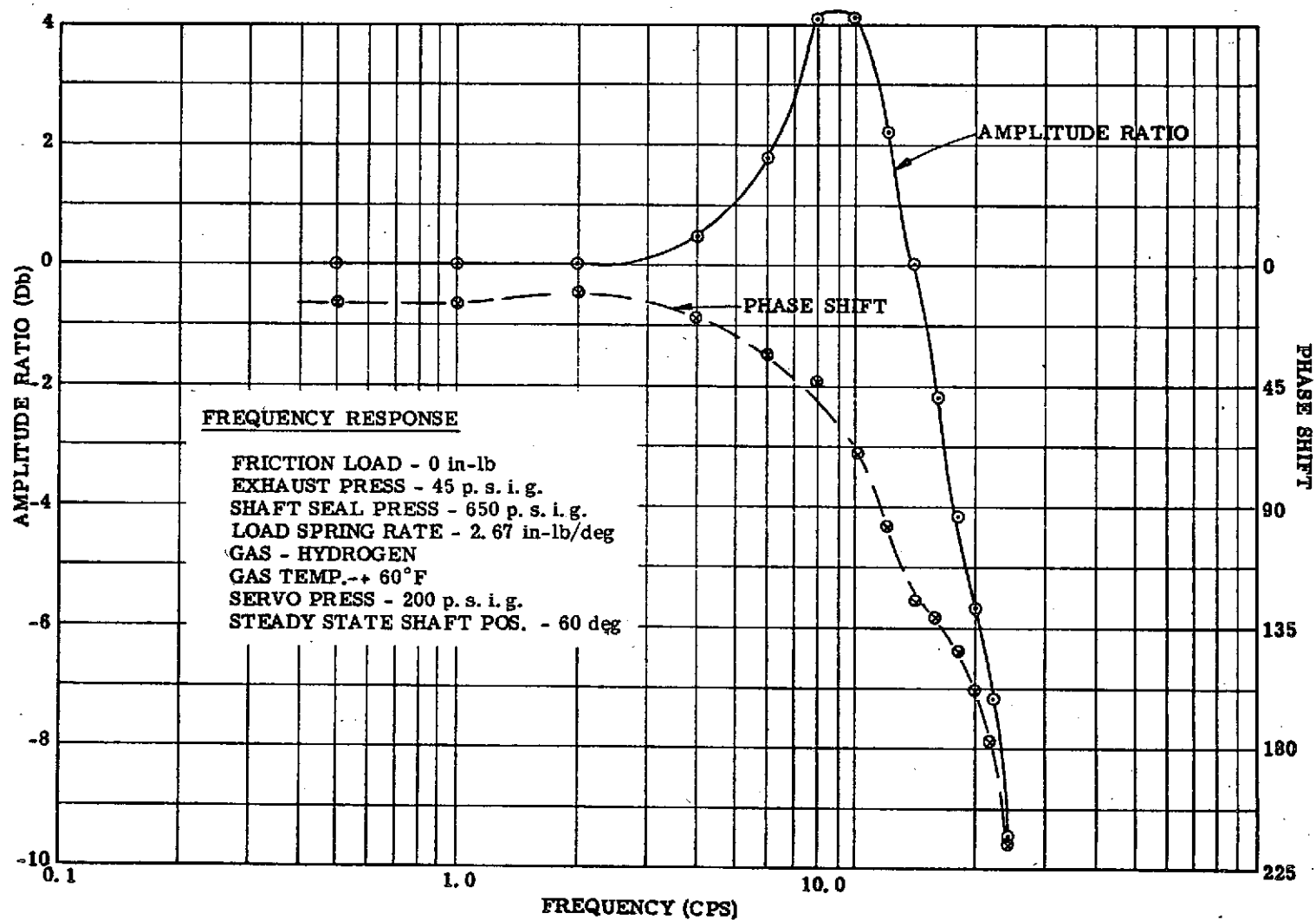
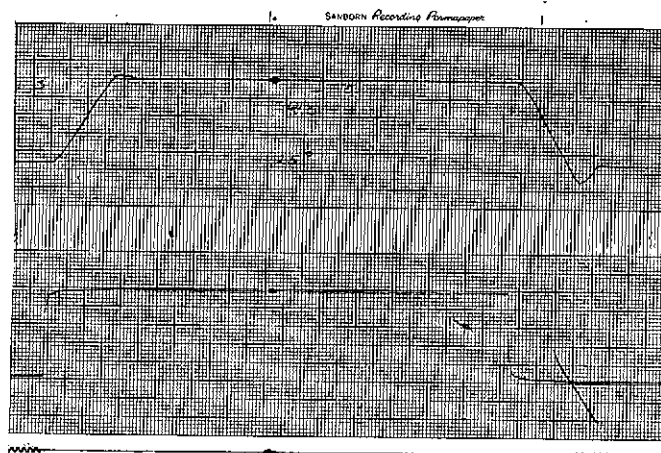


Figure 3-5. Amplitude Ratio and Phase Shift Versus Frequency Response (CPS)

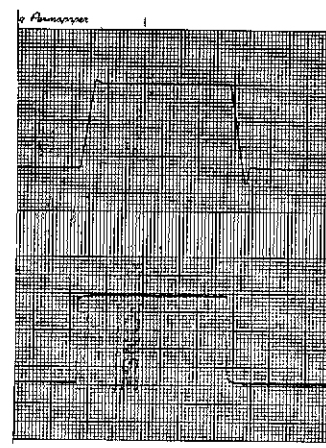


A. TRANSIENT RESPONSE AND SLEW VELOCITY
PAPER SPEED: 100 MM/SEC.

OUTPUT SHAFT
POSITION:
2.0 DEG/MM

STEADY-STATE
OUTPUT SHAFT
POSITION: 42°

INPUT SIGNAL:
45° STEP AT
0.3 CPS.



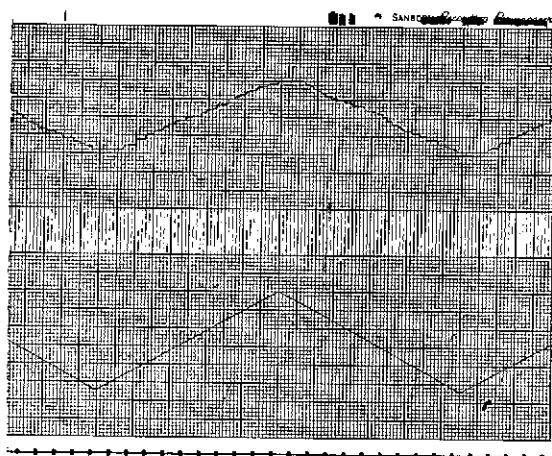
B. TRANSIENT RESPONSE
PAPER SPEED: 25 MM/SEC.

OUTPUT SHAFT
POSITION:
2.0 DEG/MM

STEADY-STATE
OUTPUT SHAFT
POSITION: 42°

INPUT COMMAND
SIGNAL: 45° SIGNAL
AT 0.3 CPS.

Friction Load: 0 in. -lb.	Gas: Hydrogen
Exhaust Pressure: 45 psig.	Gas Temperatures: Inlet: -277°F.
Shaft Seal Pressure 650 psig.	Exhaust: -248°F.
Load Spring Rate: 2.67 in. -lb./deg.	Supply Pressure: 200 psig.
	Skin Temperature: -203°F.

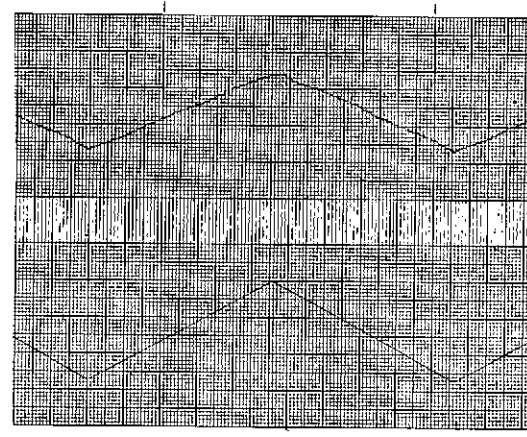


C. DYNAMIC RESOLUTION
PAPER SPEED: 5 MM/SEC.

OUTPUT SHAFT
POSITION:
0.5 DEGREES/MM

STEADY-STATE
OUTPUT SHAFT
POSITION: 60°

INPUT COMMAND
SIGNAL:
±5 DEGREE RAMP
AT 0.05 CPS.



D. DYNAMIC RESOLUTION
PAPER SPEED: 5 MM/SEC.

OUTPUT SHAFT
POSITION:
0.5 DEGREES/MM

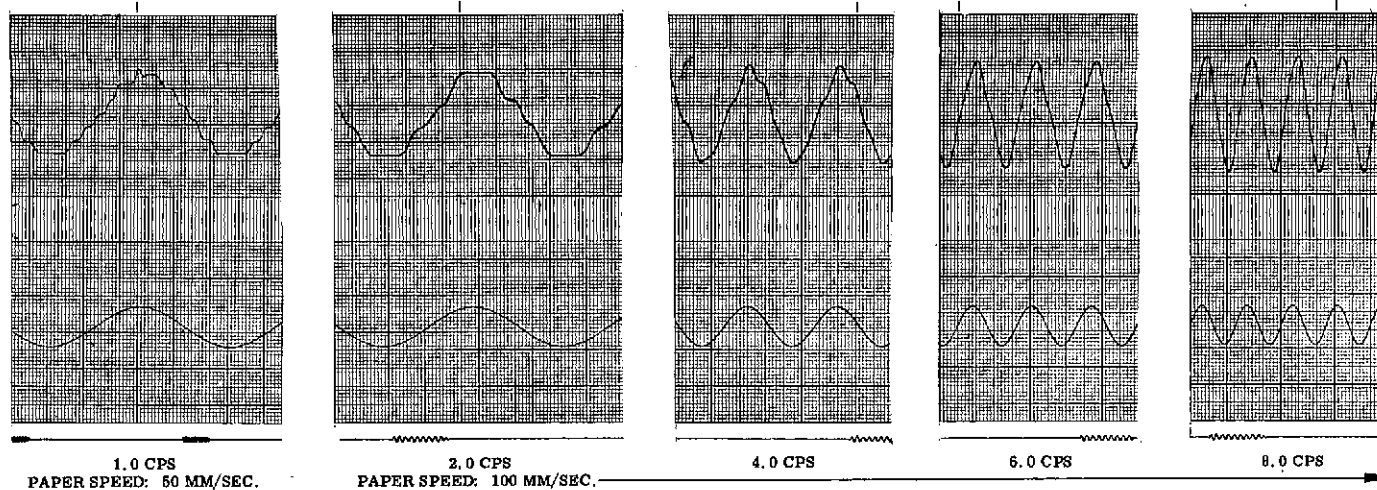
STEADY-STATE
OUTPUT SHAFT
POSITION: 20°

INPUT COMMAND
SIGNAL:
±5 DEGREE RAMP
AT 0.05 CPS.

Figure 3-6. Closed Loop Performance of TPCV Actuator (NT-B4 No. 9) Test Condition B

OUTPUT SHAFT
POSITION

INPUT COMMAND
SIGNAL:
 $\pm 2^\circ$ SINE WAVE



Friction Load: 0 in. -lbs.	Gas: Hydrogen
Exhaust Pressure: 45 psig.	Gas Temperature: -277°F .
Shaft Seal Pressure: 650 psig.	Supply Pressure: 200 psig.
Load Spring Rate: 2.67 in. -lb./deg.	Steady-State Output Shaft Position: 20°

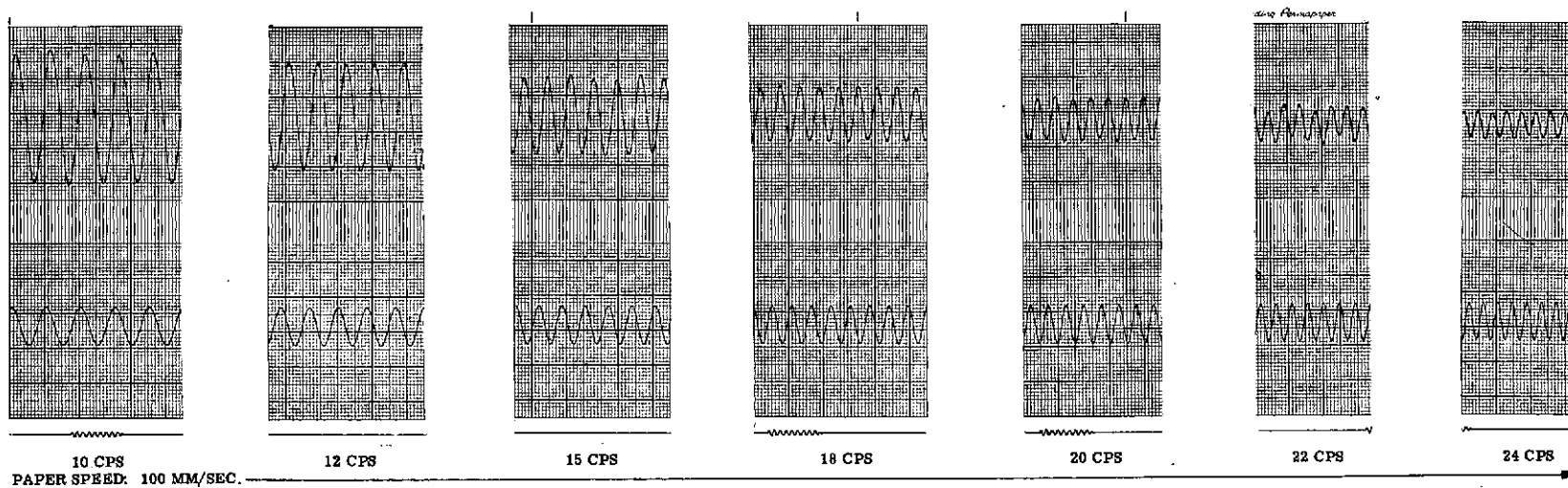


Figure 3-7. Frequency Response for Test Condition B

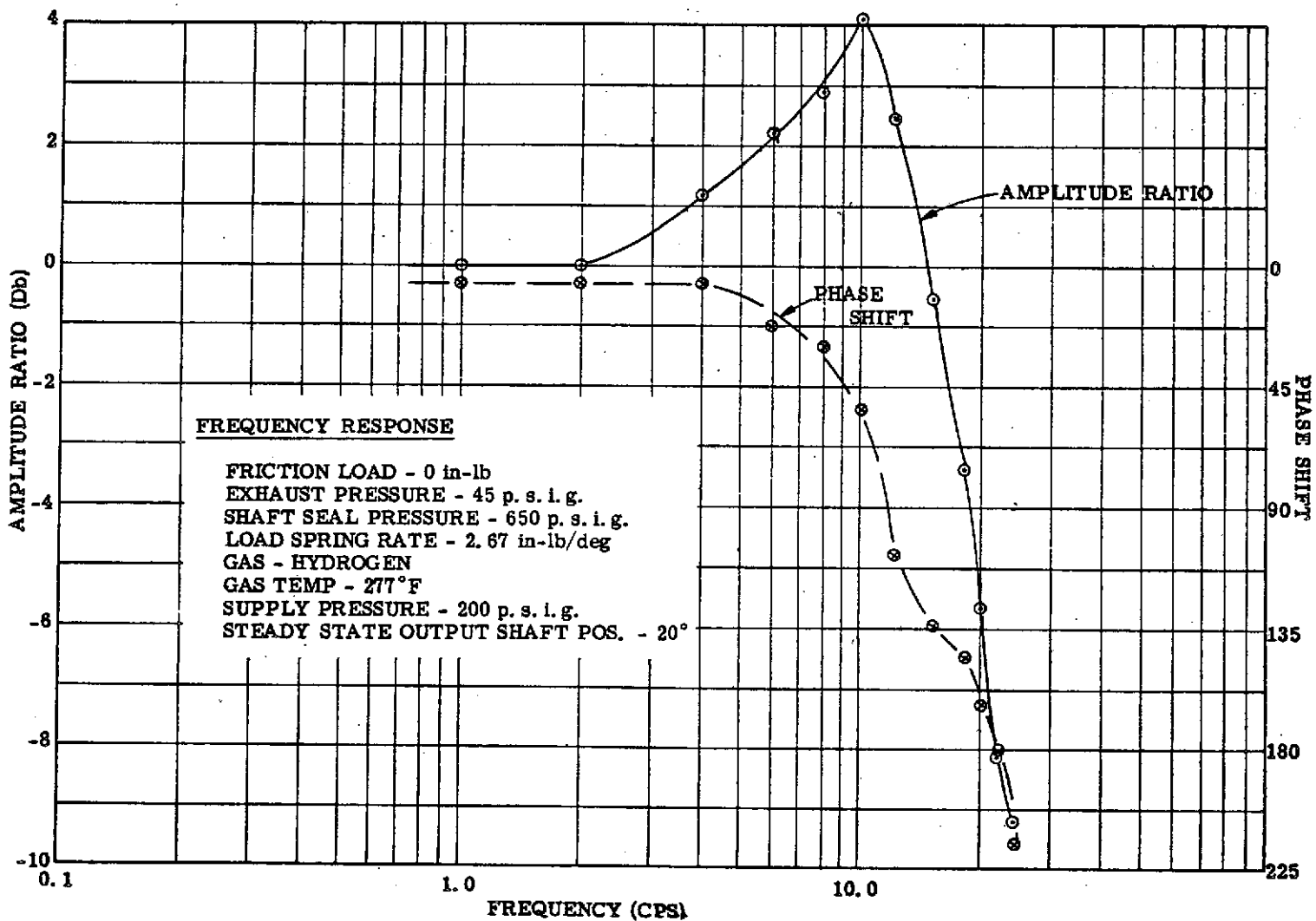
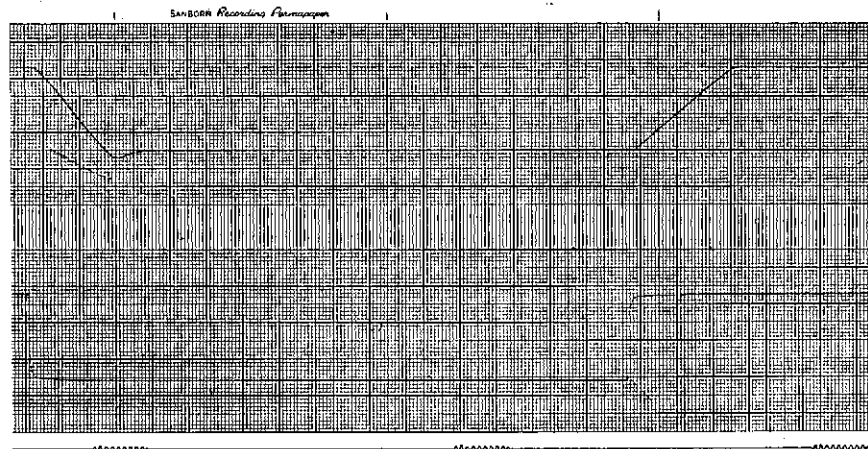


Figure 3-8. Amplitude Ratio and Phase Shift Versus Frequency (CPS)

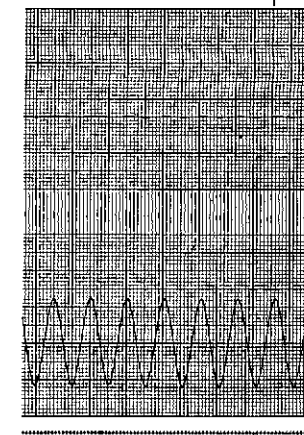


A. TRANSIENT RESPONSE AND SLEW VELOCITY
PAPER SPEED: 100 MM/SEC.

OUTPUT SHAFT
POSITION:
2.0 DEGREES/MM

STEADY-STATE
OUTPUT SHAFT
POSITION: 42°

INPUT COMMAND
SIGNAL:
45 DEGREE STEP

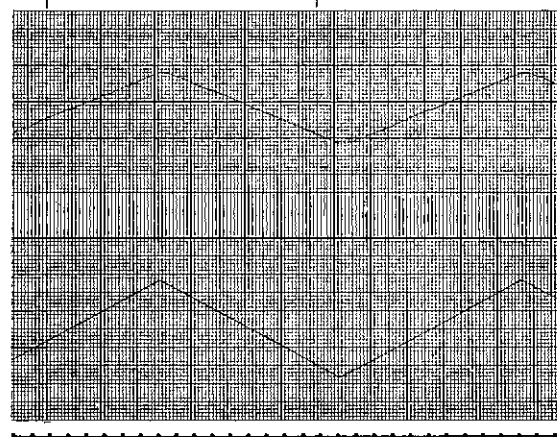


OUTPUT SHAFT
POSITION:
0.01 DEGREE/MM

STEADY-STATE
OUTPUT SHAFT
POSITION: 20°

INPUT COMMAND
SIGNAL: 0.2°
0.1 CPS SINE WAVE

Friction Load: 0 in.-lb.	Load Spring Rate: 2.67 in.-lb./deg.
Exhaust Pressure: 45 psig.	Gas: Nitrogen
Shaft Seal Pressure: 650 psig.	Gas Temperature: 60°F.
Supply Pressure: 200 psig.	



C. DYNAMIC RESOLUTION
PAPER SPEED: 5 MM/SEC.

OUTPUT SHAFT
POSITION:
0.5 DEGREE/MM

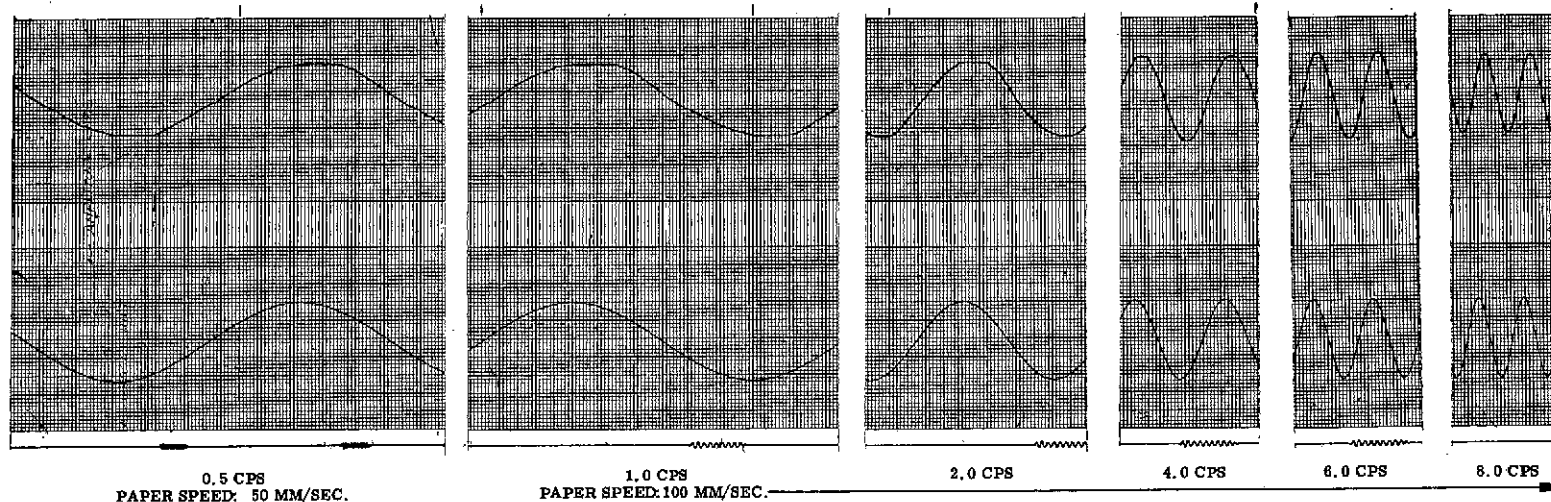
STEADY-STATE
OUTPUT SHAFT
POSITION: 20°

INPUT COMMAND SIGNAL:
± 5 DEGREE RAMP
AT 0.05 CPS.

Figure 3-9. Closed Loop Performance of TPCV Actuator (NT-B4 No. 9) Test Condition C

OUTPUT SHAFT
POSITION:
0.2 DEG/MM

INPUT COMMAND
SIGNAL:
 $\pm 2^\circ$ SINE WAVE



Friction Load: 0 in. -lb.	Gas: Nitrogen
Exhaust Pressure: 45 psig.	Gas Temperature: 60°F.
Shaft Seal Pressure: 650 psig.	Supply Pressure: 200 psig.
Load Spring Rate: 2.87 in. -lb./deg.	Steady-State Output Shaft Position: 20 deg.

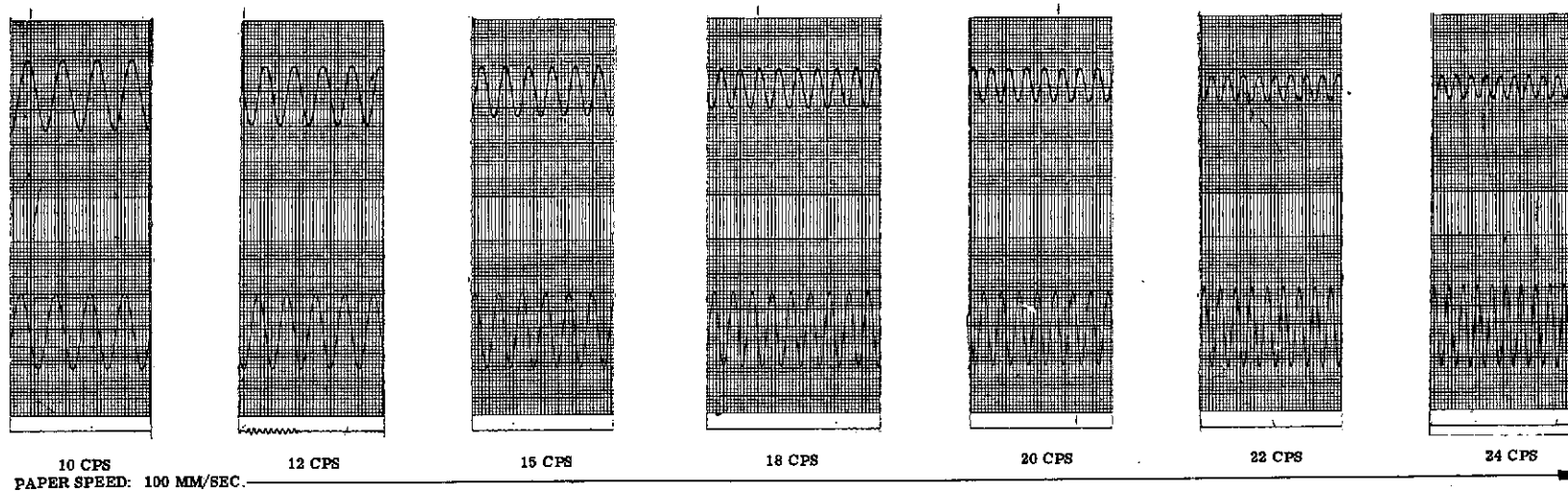


Figure 3-10. Frequency Response for Test Condition C

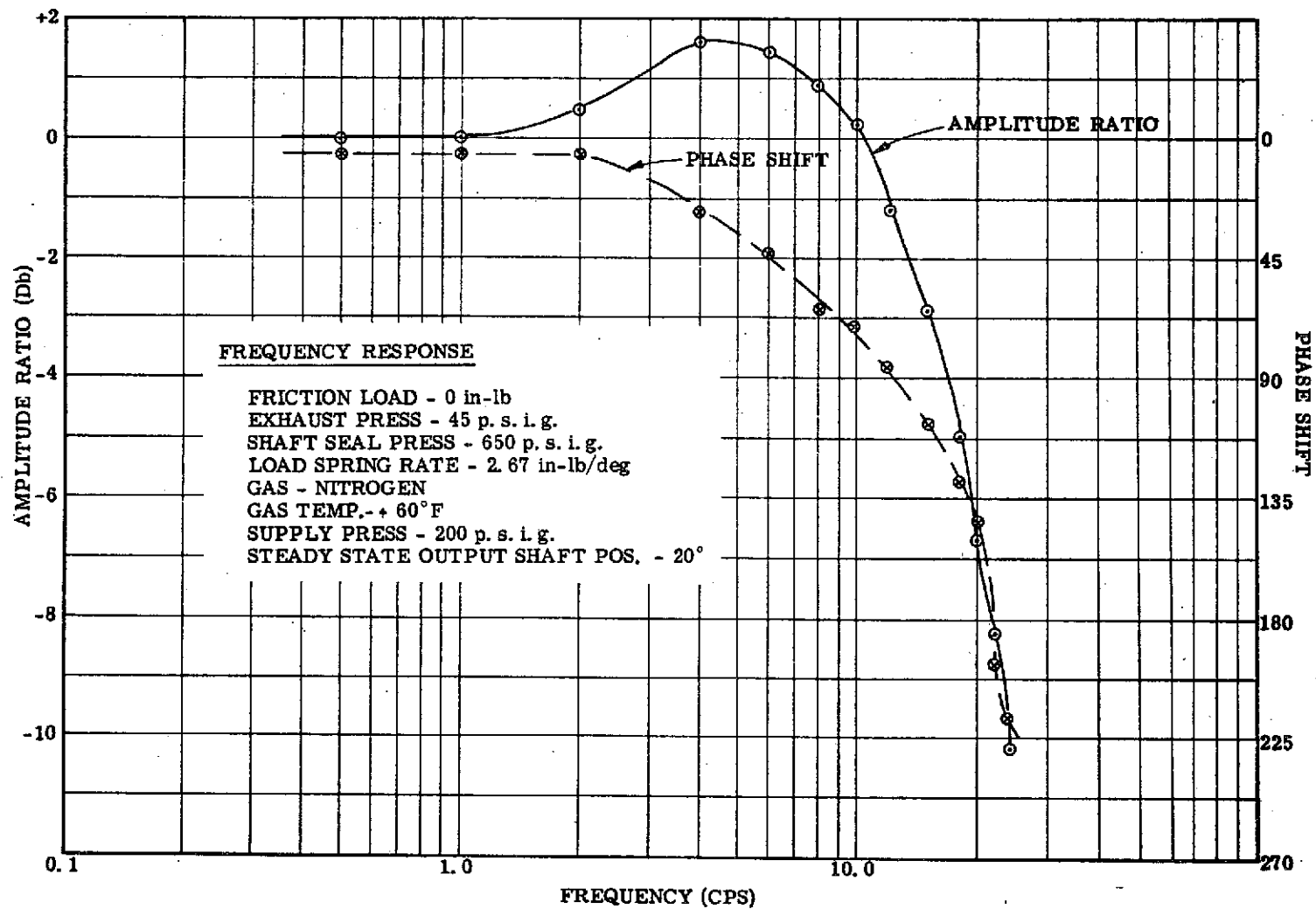


Figure 3-11. Amplitude Ratio and Phase Shift Versus Frequency (CPS)

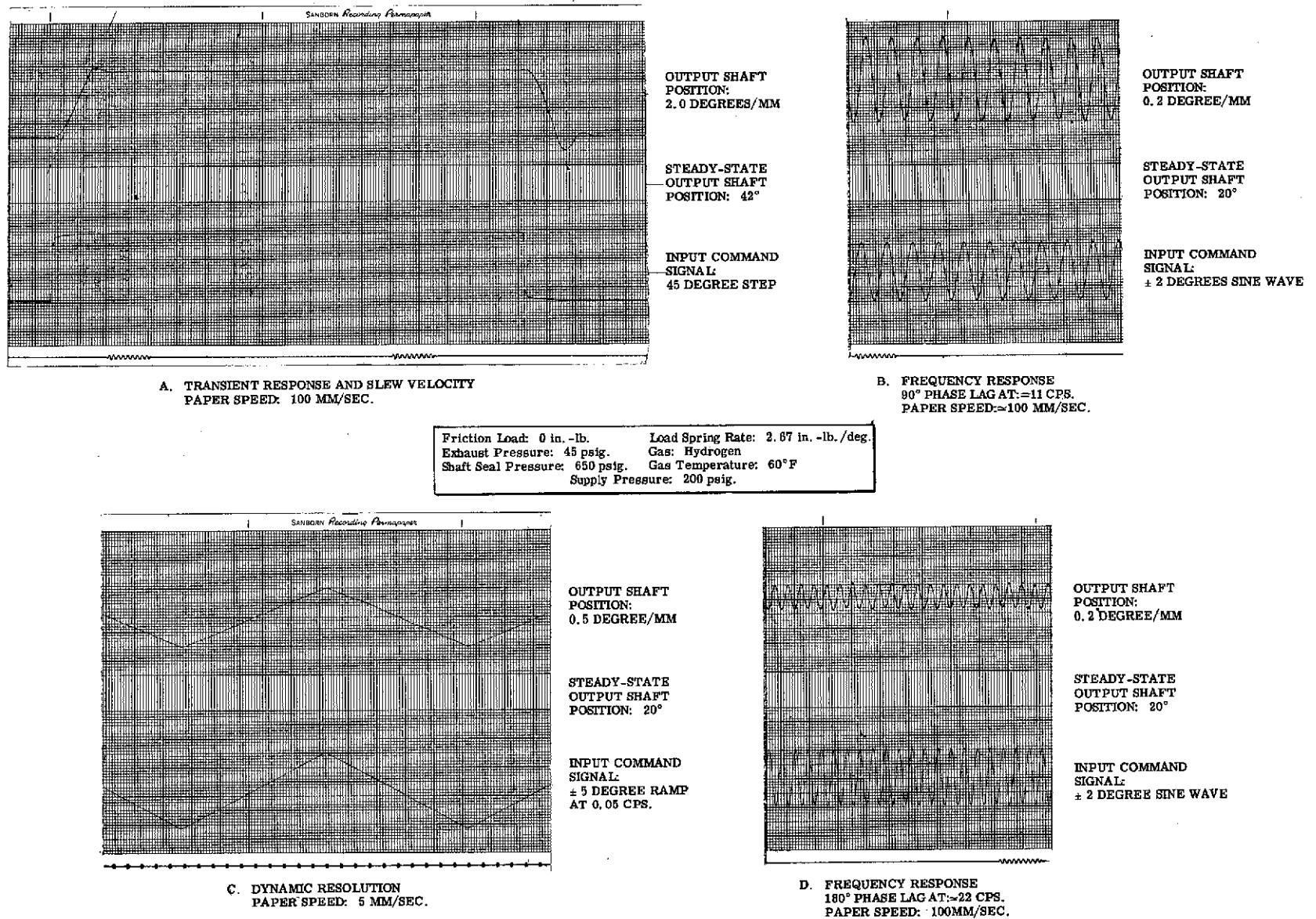


Figure 3-12. Final Calibration Data